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Journal of Environmental Planning and Management

ISSN: 0964-0568 (Print) 1360-0559 (Online) Journal homepage: http://www.tandfonline.com/loi/cjep20

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To cite this article: Benjamin Spencer, Josh Lawler, Celia Lowe, LuAnne Thompson, Tom Hinckley, Soo-Hyung Kim, Susan Bolton, Scott Meschke, Julian D. Olden & Joachim Voss (2016): Case studies in co-benefits approaches to climate change mitigation and adaptation, Journal of Environmental Planning and Management

To link to this article: http://dx.doi.org/10.1080/09640568.2016.1168287

Published online: 21 Jun 2016.

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Journal of Environmental Planning and Management, 2016
http://dx.doi.org/10.1080/09640568.2016.1168287

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Case studies in co-benefits approaches to climate change mitigation and adaptation

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(*Received 20 July 2014; final version received 8 March 2016*)

Attempts to mitigate greenhouse gas emissions or manage the effects of climate change traditionally focus on management or policy options that promote single outcomes (e.g., either benefiting ecosystems or human health and well-being). In contrast, co-benefits approaches to climate change mitigation and adaptation address climate change impacts on human and ecological health in tandem and on a variety of spatial and temporal scales. The article engages the concept of co-benefits through four case studies. The case studies emphasize co-benefits approaches that are accessible and tractable in countries with human populations that are particularly vulnerable to climate change impacts. They illustrate the potential of co-benefits approaches and provide a platform for further discussion of several interdependent principles relevant to the implementation of co-benefits strategies. These principles include providing incentives across multiple scales and time frames, promoting long-term integrated impact assessment, and fostering multidimensional communication networks.

Keywords: human health; ecological health; incentives; impact assessment; multidimensional networks

1. Introduction

Rising sea levels, higher globally averaged temperature, and the decreasing extent of Arctic summer sea-ice can now be attributed to emissions from fossil fuel combustion (IPCC 2013). Without a substantial and immediate reduction in fossil fuel emissions, the effects of climate change will affect the planet and human life for centuries to millennia (Solomon *et al*. 2009). Anthropogenic climate change has been linked to changes in the timing of ecological events and the distributions of plants and animals (IPCC 2014). By the end of the twenty-first century, it is very likely that the global surface temperature will exceed its preindustrial average by 1.5 °C, that precipitation intensity will increase,

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that heavier precipitation events and drought will become more frequent, and that global drylands will expand (IPCC 2014). These changes will impact both human and natural systems and have particularly adverse effects for vulnerable human populations in developing tropical and subtropical countries (Costello *et al*. 2009).

Climate change impacts range from global to local, from gradual and subtle to immediate and extreme. They involve complex interactions of human systems with ecological and physical systems that have both direct and indirect impacts on human and ecological health. Mitigation of climate change by reducing or preventing the emission of greenhouse gases can interact with adaptation efforts and, increasingly, the interaction of mitigation and adaptation has been taken into account when planning for the future. However, there are trade-offs between the two that must be considered (IPCC 2014). Examples where this is dramatically illustrated include (1) the responses of diverse populations (from villages along the Indus Delta (Salik *et al*. 2015) to urban areas such as Copenhagen) to sea level rise (Hallegatte *et al*. 2011), and (2) efforts to reduce forest change and loss resulting from climate change impacts on fire behavior and effects and species−environmental distribution envelopes (Wimberly and Liu 2014). Disciplinary silos impede cross-fertilization among health, environmental, and social scientists and professionals in the development of safe, effective, and affordable climate change solutions. Berry *et al*. (2015) find that in studies of adaptation and mitigation in Europe, co-benefits were not often mentioned. Political and bureaucratic divisions limit collaboration between local, regional, national, and international governing bodies. Policies are often uninformed and unresponsive to situations in communities of greatest need. For instance, Suckall, Tompkins, and Stringer (2014) discuss that for communities in Zanzibar, there are trade-offs between adaptation and mitigation for individual farmers. In addition, governance and resource barriers inhibit more synergistic approaches. Moser (2014) describes how climate change communication has also been a barrier to public and governmental action, especially in the United States. The individual and community support necessary for increasing ecosystem resilience which can result in dual benefits in mitigation and adaptation (e.g., reduced forest fire and insect risks), for example, is mixed, and funding and infrastructure to support is often lacking in spite of large losses in ecosystem services and property (e.g., fires in Australia, western United States and Canada, Portugal, and Greece).

Attempts to mitigate greenhouse gas emissions or manage the effects of climate change traditionally focus on management or policy options that promote single outcomes (e.g., either benefiting ecosystems or human health and well-being) rather than a broad set of results. Emphasis is often placed on long-term goals and large-scale solutions, especially with respect to mitigation. For instance, until recently, the Framework Convention on Climate Change negotiations has focused on emissions reduction (Gupta 2010). Many mitigation and adaptation strategies have intended or unintended 'co-benefits' or 'co-harms' across multiple sectors, scales and timeframes, which are often substantial but overlooked (Hamilton and Akbar 2010).

The discussion and quantification of co-benefits originally focused primarily on climate change mitigation (Cheng and Berry 2013). Reducing urban air pollution due to a reduction of burning of fossil fuels and their associated carbon emissions is an oft-cited example of a mitigation strategy with co-benefits since it improves urban air quality, reduces pulmonary disease, and decreases climate change emissions (Younger *et al*. 2008; Haines *et al*. 2009; Nemet, Holloway, and Meier 2010). More recently, similar principles have become increasingly prevalent in discourse related to climate change adaptation. Shaw *et al*. (2014) note in a study of local government response to a carbon neutral requirement that an integrated sustainability strategy can achieve both adaptation and mitigation goals. In

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agroforestry, improving the state of the small-holder farms, while at the same time sequestering carbon, can have additional benefits for farmers (Lasco, Delfino, and Espaldon 2014). The conservation of riparian floodplains supports a river's ecological systems, preserves fish populations as a source of nutrition, and provides protection from flood events (Gregory *et al*. 1991). Rather than addressing human health and well-being at the expense of ecological health or vice versa, co-benefits approaches have the potential to reduce climate change's negative impacts on human and ecological health in tandem. Rather than focusing primarily on long-term goals and large-scale solutions, co-benefits approaches address immediate, intermediate and long-term, local, regional, and global concerns concurrently. The definition of co-benefits approaches can be expanded to include factors such as economics and social capital. Indeed, in many cases, co-benefits approaches might be better described as 'multi-benefits' approaches.

The present article engages co-benefits approaches as they relate to climate change mitigation and adaptation through the lens of four case studies:

(1) The United Nations Reducing Emissions from Deforestation and Forest Degradation Plus Program in Indonesia (REDD+ Indonesia);
(2) The Guyana Mangrove Restoration Project, Guyana (GMRP);
(3) Sustainable Water Management Improves Tomorrow's Cities Health, Lima, Peru (SWITCH);
(4) Soil and Water Conservation Management, Sahel region (SWCM).

These case studies present co-benefits as a conceptual framework that guides climate mitigation and adaptation strategies. They serve as localized examples of the kinds of impacts that co-benefits approaches can have on the environment and human well-being. Drawing upon relevant theory and the positive and negative lessons that each of the case studies provides, we argue that co-benefits approaches that bring together tangible incentives across multiple spatial and temporal scales, long-term integrated impact assessment, and multidimensional communication networks have the potential to multiply the positive impact of climate change mitigation and adaptation efforts (Figure 1).

Figure 1. Location of selected co-benefits case studies. Artwork (modified): Patrick. Accessed 10 June 2014. http://upload.wikimedia.org/wikipedia/commons/a/ac/World_map_between_2003_and_2005.png. GNU Free Documentation License, Version 1.2. http://commons.wikimedia.org/wiki/Commons:GNU_Free_Documentation_License,_version_1.2.

2. Case study selection

Case studies were selected based on several common characteristics (see Table 1). They all have demonstrated ecological benefits and the potential to provide social benefits including human health, economic, cultural, or other benefits. They consist of place-based projects and programs rather than more general technologies or methods, emphasizing the importance of context. In recognition of the heightened vulnerability of populations in developing countries to climate change impacts, all of the case studies emphasize co-benefits strategies that are accessible and tractable in these settings. Many of them incorporate low-cost 'green' infrastructure. In addition, all of the case studies are located in the tropics where, relative to temperate zones, the changing climate will rise above local climate variability sooner and because the populations are, in general, more vulnerable in the tropics (Mora *et al*. 2013).

Table 1. Characteristics of selected case studies.

Case study characteristics	REDD+	GMRP	SWITCH	SWCM
Co-benefits	Yes	Yes	Yes	Yes
Developing/developed country	Developing country	Developing country	Developing country	Developing country
Latitude	Tropics	Tropics	Tropics	Tropics
Geographical context	Indonesia	Guyana	Peru	Sahel
Climate change cause or impact	Deforestation	Sea level rise	Water scarcity	Drought/food insecurity
Land-use context	Deforestation	Coastal development	Urbanization	Desertification
Mitigation/adaptation	Primarily mitigation	Primarily adaptation	Primarily adaptation	Primarily adaptation

Operating within the framework of these shared characteristics, case study selections were further refined based upon their unique characteristics. Each case study responds to a different climate change cause or impact (deforestation, sea level rise, water scarcity, and drought impacted food security), is located in a different geographic, cultural, and ecological context (Indonesian forests, the Caribbean coast of Guyana, the coastal desert of Peru, and the semi-arid shrublands of the Sahel), and relates to a different land-use change (deforestation, coastal development, urbanization, and desertification). By comparing different types of co-benefits case studies, the article argues for the generality of a co-benefits approach. Finally, all of the case studies address both mitigation and adaptation to varying degrees. In doing so, they reaffirm that mitigation strategies can have co-benefits related to adaptation and vice versa.

The first case study, REDD+, focuses on a co-benefits approach to mitigation that also has co-benefits as an adaptation strategy. It serves as an entree to the subject matter and acts as a bridge to the subsequent presentation of case studies, GMRP, SWITCH, and SWCM, which focus primarily on adaptation.

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3. Case studies

*3.1. Case study 1: the United Nations reducing emissions from deforestation and forest degradation plus program in Indonesia (***REDD+ Indonesia***)*

Organizations/Stakeholders: UN, FAO, Government of Indonesia, Business, Civil Society Organizations, Government of Norway, Forest Dependent Peoples.

Location: Indonesia

Dates: 2006−present (Figure 2; Figure 3)

Figure 2. Deforestation in Indonesia in the context of REDD+. Photo: Rainforest Action Network, Indonesia. Accessed 18 January 2014. http://www.flickr.com/photos/rainforestactionnetwork/5680740395/2014. Creative Commons, Attribution-Non-Commercial 2.0 Generic CC BY-NC 2.0. https://creativecommons.org/licenses/by-nc/2.0/.

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Indonesia is the third largest emitter of greenhouse gases in the world owing to its high rate of deforestation, land-use change, and burning and drying of peat-lands (PEACE 2007). REDD+ Indonesia is a climate mitigation strategy that responds to these issues using a payment for ecosystems services model. The program provides compensation for activities that slow down the widespread degradation of forests and peat-lands and result in verifiable reductions in greenhouse gas emissions. The aim is to reduce Indonesia's carbon emissions by 26%−41% by 2020. REDD+ Indonesia involves stakeholders at international, national, and provincial levels. However, it has been criticized for its failure to engage many of Indonesia's indigenous populations (Forest Peoples Programme 2011). To reach this goal, the program consists of three major phases: (1) a preparation phase (2007−2009) focused on developing a national climate and forest conservation and management strategy, along with enabling policies and institutional reforms, (2) a readiness phase (2009−2012) focused on developing a National Action Plan, methods to meet emissions reductions targets, and pilot projects in Kalimantan and Sulawasi, and (3) a full implementation phase (2012−2020) focused on

Figure 3. Indonesian agro-ecosystems in the context of REDD+. Photo: contributing author.

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deploying REDD+ mechanisms at a national level (Norway 2010; Edwards, Koh, and Laurance 2012).

Indonesia's REDD+ efforts to reduce climate change emissions through forest conservation and sustainable forest management have the potential to provide multiple environmental benefits, including the maintenance of intact forest ecosystems, habitat and species diversity, the purification of air, and water and soil conservation. Intact forest ecosystems in turn provide immediate, intermediate, and long-term health benefits to forest-dependent peoples, including mental well-being derived from cultural continuity, clean water, nutritional and spiritual value of forest-derived foods, and protection from natural resource violence. They also provide benefits to non-forest-dependent peoples by slowing the rate of emergence of vector-borne disease, preserving biodiversity for aesthetic or medicinal purposes, decreasing disease loads near forests, and maintaining reserves for pharmaceutical products (Colfer *et al*. 2006; Muriuki 2006; Vittor *et al.* 2006; Wilcox and Ellis 2006; Karjalainen, Sarjala, and Raitio 2010; Donovan *et al*. 2013).

Despite its formal emphasis on climate change mitigation, REDD+ Indonesia also has the potential to facilitate climate change adaptation. Forests safeguard ecosystem services such as non-timber forest products (e.g., food and fuel) that sustain populations on a daily basis, provide protection from flooding and landslides during large precipitation events, and sustain watersheds that support small- and large-scale agriculture across Indonesia (Pramova and Locatelli 2013).

3.2. Case study 2: The Guyana Mangrove Restoration Project (GMRP)

Organizations/Stakeholders: Government of Guyana, European Union, Ministry of Agriculture National Agriculture Research Institute (NARI).

Figure 4. Seawall in Georgetown, Guyana. Photo: Richards, A. 2014. "Waves at Ogle." Accessed 10 June 2014. https://www.flickr.com/x/t/0092009/photos/arichards-gallery/6848905956/. Creative Commons, Attribution-Non Commercial-NoDerivs 2.0. https://creativecommons.org/licenses/by-nc-nd/2.0/.

Location: Coastal Guyana
Dates: 2010–2012 (Figure 4; Figure 5)

A large majority (ca. 90%) of Guyana's human population lives in flood-prone coastal areas. Portions of the coast, including the capital city of Georgetown, are already 0.5–1 m below sea level and rely heavily on sea walls to prevent flooding. Relative sea levels over the last several decades in Guyana have been rising at a rate of 10.2 mm per year, roughly five times the global average rate (Guyana National Climate Committee 2002). As sea levels continue to rise in response to warming oceans and melting glaciers and polar ice-sheets, local communities will be at even greater risk from storm surges and coastal flooding.

The Guyana Mangrove Restoration Project attempts to reduce the impacts of climate change through the protection, rehabilitation, and sustainable use of Guyana's mangrove ecosystems. The project seeks to maintain the protective function of mangrove ecosystems as well as support other human values and biodiversity, without compromising socio-economic development. It engages a wide range of stakeholders at international, national, and local levels and involves the establishment of national policies, regulatory standards, and a National Mangrove Coordination Committee to promote interagency cooperation on mangrove conservation, restoration, and use. Mangrove restoration projects at pilot sites incorporate community-based outreach, education, and enforcement. Pilot site communities participate in mangrove restoration planning, mangrove replanting, and monitoring and evaluation processes. In many instances, GMRP facilitators work with community members to develop small businesses, such as honey production, that depend upon and support mangrove health (NARI 2010).

The GMRP has the potential to produce immediate and long-term co-benefits to ecological and human health, as well as economic benefits that manifest at local,

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Figure 5. Mangrove seedlings on the coast of Mon Repos, Guyana. Photo: Richards, A. 2011. "Atlantic Coast at Mon Repos, ECD." Accessed 2 October 2013. http://www.flickr.com/photos/arichards-gallery/6114466168/in/set-72157629734746543. Creative Commons, Attribution-Non Commercial-NoDerivs 2.0. https://creativecommons.org/licenses/by-nc-nd/2.0/.

regional, and global scales. From an ecological perspective, functioning mangrove systems provide nutrient-rich, near-shore habitat for many marine crustaceans, mollusks, and fish (Zhang *et al*. 2012). At the global scale, mangrove restoration has the potential to reduce or mitigate atmospheric carbon dioxide concentrations through carbon sequestration (reviewed in Barbier *et al*. 2011).

In terms of human health and economic benefits, protecting and restoring mangrove forests have the potential to prevent flooding-related deaths, injuries, and damage to human property. The sheltered waters beneath the mangroves serve as nurseries for many valuable fisheries, and mangrove forests provide products such as honey and timber. These fisheries and other products serve as valuable sources of nutrition and income generation in nearby communities.

While GMRP's co-benefits have not been quantified and published, several studies have attempted to assess the various co-benefits of mangrove protection and restoration. For example, mangrove forests in the Gulf of California account for 32% of the fish and crab landings (Aburto-Oropeza *et al*. 2008). In Vietnam, the benefits of mangrove restoration – measured in terms of timber, fish, honey, and avoided sea-dike maintenance – outweighed the economic costs – measured as planting and thinning costs – by a ratio of roughly 5 to 1 (Tri, Adger, and Kelly 1998). A comparative accounting of the benefits – including coastal protection, wood products, and fisheries habitat – of preserving mangroves versus converting them to shrimp farms in Thailand showed that the optimal economic gain resulted from allowing up to 20% of the mangrove forest to be converted and the remaining 80% or more to be preserved (Barbier *et al*. 2008). In this example, the largest economic benefits of preserving the mangroves were from increased coastal protection.

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Monitoring and evaluation reveals that, in Guyana, one of the challenges to restoring mangrove forests has been the loss of newly planted trees to wave action. In fact, it appears that even more established forests are often lost in storms. In response, the GMRP has been experimenting with combining hard infrastructure and restoration using detached breakwaters (geotextile tubes). As sea level rises and storms become more frequent and intense, such strategic combinations of 'hard' and 'soft' adaptation strategies will likely be necessary in many locations.

3.3. Case study 3: sustainable water management improves tomorrow's cities health, Lima (SWITCH)

Organizations/Stakeholders: *International* – UNESCO-IHE and the General Directorate for Research of the European Union. *Lima* – Community groups, municipal government agencies, universities, Ministry of Housing, Building and Sanitation, National Superintendency of Sanitation Services, Ministry of the Environment, Ministry of Health/General Directorate of Environmental Health, National Water Authority.

Location: Lima, Peru

Dates: 2006–2011 (Figure 6; Figure 7).

Figure 6. An informal urban settlement in Lima, Peru, lacking reliable water supplies and public green space. Photo: contributing author.

More than a third of Lima's 9 million occupants live in slums, many without reliable access to clean water, adequate nutrition, or public green space (Riofrio 2003). In less than 50 years, glaciers below 5,500 m (a major source of Lima's water supply) are expected to melt as a result of climate change. At the same time, the city's population is increasing dramatically. These factors will contribute to significant water shortages within the next two decades (Leavell 2007; Lubovich 2007; Painter 2007).

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Figure 7 Public green space and urban agriculture irrigated with wastewater in Lima, Peru. Photo: contributing author.

The SWITCH Project focused on wastewater recycling for productive use in public spaces in anticipation of future water scarcity. It targeted two primary levels of intervention: (1) the development of sector-specific and national policy guidelines related to wastewater reuse and (2) the participatory planning, design, and implementation of a demonstration 'eco-productive' park in a neighborhood with very limited green space. The development of policy guidelines was informed by the quantitative and qualitative assessment of existing wastewater reuse in the city and related regulatory frameworks. The demonstration park's multifunctional 2-hectare design included areas for recreation, exercise, and the productive cultivation of plants for sale. A nearby primary and secondary water treatment facility and an on-site tertiary wastewater treatment pond provided irrigation for the park's vegetation. The park served to substantiate policy guidelines at a local level and facilitated their approval by the Peru's national government. The project incorporated a local 'Learning Alliance' that included community groups, local NGOs, local government and universities, and a national Learning Alliance that included a range of government institutions. Learning Alliances served as a means of sharing information and building capacity in wastewater recycling across sectorial and hierarchical boundaries (Castro, Merzthal, and van Veenhuizen 2012). Shortly after the completion of SWITCH Lima and SWITCH projects in other cities, the SWITCH Consortium published their outcomes. They provide a set of guidelines describing SWITCH processes, such as starting Learning Alliances, rapid urban water assessment, promoting equity, monitoring and evaluation and workshop facilitation (Butterworth, McIntyre, and da Silva Wells 2011).

The SWITCH project represents a climate change adaptation strategy with potential co-benefits to human and ecological health at multiple scales. From an ecological perspective, wastewater recycling reduces wastewater discharge to rivers and the ocean that protects coastal ecosystems (Rabalais *et al.* 2009). It also reduces demand for limited water resources. As a source of irrigation, it contributes to the growth of urban forests that reduce air pollution, reduce urban heat island effects, and sequester carbon (Brack 2002). Projects

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like SWITCH also have the potential to increase awareness of the water cycle and the impacts of water consumption, fostering an ethic of water conservation.

With respect to human health, the reuse of treated wastewater decreases use of drinking water for irrigation, increases water supplies for domestic use and contributes to better hygiene practices. It decreases use of untreated wastewater for irrigation and contributes to decreased incidence of fecal–oral disease transmission. It increases access to public green space with positive effects on the physical and mental well-being of residents. Finally, as it increases the supply of water available for urban agriculture, it has the potential to significantly improve urban food security (Jiménez *et al*. 2010; Nurse *et al*. 2010).

3.4. Case study 4: soil and water conservation management (SWCM)

Organizations/Stakeholders: Farmers in Niger and Burkina Faso, NGOs and government agencies including Oxfam and USAID.

Location: Burkina Faso and Niger (Sahel region)

Dates: 1980–present (Figure 8; Figure 9).

Figure 8. View of the village of Bani, Northern Burkino Faso, Western Sahel. Photo: Jones, Adam. Accessed 10 June 2014. https://www.flickr.com/photos/adam_jones/4815292981/in/set-72157624399214923. Creative Commons Share-Alike 3.0 Unported (http://creativecommons.org/licenses/by-sa/3.0/).

From the mid-1960s until the 1990s, average annual rainfall declined by 25%–30% in the Sahel region of West Africa, leading to widespread drought, food shortages, expansion of agriculture onto unsuitable lands, soil erosion, and depleted vegetation cover and soil fertility (Mortimore 2010). In the 1980s, the stresses on local agriculture and human communities resulted in a variety of adaptive responses and a re-evaluation of land management practices. Non-governmental organizations in the region began working with farmers to improve soil productivity and water retention, using soil and

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Figure 9. Zai holes, a traditional planting technique in Burkina Faso and many areas of the western Sahel. Photo: Abossuet, A. 2008. Women sowing okra in zai holes. Accessed 1 October 2012. http://www.flickr.com/photos/30450178@N07/7175750825/. Creative Commons, Attribution-Non Commercial 2.0 Generic. https://creativecommons.org/licenses/by-nc/2.0/.

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water conservation management (SWCM) practices including traditional planting pits, stone bunds (stones laid on contour), and permeable rock dams (Reij, Tappan, and Belemvire 2005). Earlier atmospheric science research claimed that a greener landscape could enhance rainfall, suggesting that by supporting vegetation, rainfall could increase (Charney, Stone, and Quirk 1975).

Using Participatory Rural Appraisal, Reij, Tappan, and Belemvire (2005) surveyed households in the northern Burkina Faso Central Plateau and evaluated a 35-year time series (1968–2002) of agriculture statistics, population census data, and aerial photographs. The study demonstrated that, over the long term (20 years or more), SWCM practices spread beyond areas where NGOs had actively encouraged its use and provided multiple benefits to the environment and local communities. Environmental benefits included reductions in soil loss, increased groundwater retention, increased vegetation cover, and reduced agricultural expansion into natural areas. Improvements in human health and well-being resulted from increased yields of staple crops, stability of the amount of cultivated area, more forage for livestock, less migration out of the villages, and less rural poverty as defined by the villagers themselves. Quantified examples of the likely benefits arising from SMWC include an increase in average millet and sorghum yields by 50%–60% between the mid-1980s and the mid-2000s and an increase in population growth in 12 study villages from 0% between 1975 and 1985 to 25% between 1985 and 1996 (Reij, Tappan, and Belemvire 2005).

Over this time period, the long-term drought abated and changes in rainfall contributed to re-greening (Giannini *et al*. 2008). Although some researchers argued that changes in land cover helped to increase local rainfall, recent studies indicate that early estimates of the size of this effect were incorrect, and that positive feedbacks to rainfall are likely small (Giannini, Biasutti, and Verstraete 2008) and may even be negative (Taylor *et al*. 2013). Long-term changes in rainfall in the Sahel are instead related to variations in tropical Pacific sea surface temperature and to anthropogenic greenhouse gas and aerosol forcing (Giannini, Biasutti, and Verstraete 2008; Dong and Sutton 2015).

4. Discussion

Operating at different spatial and temporal scales across diverse geographies, each of these case studies responds to a different climate change challenge and engages unique conditions of place. Their diversity compliments the diverse and contextually dependent interactions of human and ecological systems. The collective consideration of case studies and related theory suggest a number of underlying, interdependent principles that serve as conceptual guide posts in the deployment of climate mitigation and adaptation strategies that seek to maximize human health, environmental, social, economic, and other co-benefits. These principles are summarized in Table 2.

Table 2. Principles of co-benefits strategies.

Co-benefits principles	REDD+	GMRP
Provide incentives		
Stakeholders	International, national, provincial	International, national, local
Short-term incentives	Carbon credits, ecosystem services	Food, products, income
Long-term incentives	Carbon sequestration, ecological conservation	Coastal flood protection, ecological conservation
Promote impact assessment		
Time extent	Short term	Short-/mid-term
Ecohealth metric	No	No
Foster communication networks		
National/international	REDD+ working group	National Mangrove Coordination Committee
Local	Limited representation	Coastal communities
	SWITCH	SWCM
Provide incentives		
Stakeholders	International, national, municipal, local	International, national, local
Short-term incentives	Income, public green space	Food, income
Long-term incentives	Water, ecological conservation	Water, ecological conservation
Promote impact assessment		
Time extent	Short term	Long term
Ecohealth metric	No	No
Foster communication networks		
National/international	National Learning Alliance/ SWITCH Consortium	International NGOs
Local	Local Learning Alliance	Villages, farmers

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4.1. Provide incentives at multiple scales and timeframes

Bossel (1999) argues that people have different 'horizons' that determine the degree to which they engage in the world. The most intimate of these horizons, which involves the immediate and direct needs of an individual, family members and, in some cases, other community members, and below which individuals are willing to invest their own time and resources, he terms 'the horizon of responsibility'. The next level in Bossel's scale, 'the horizon of attention', involves issues or activities in which an individual takes an interest, but does not necessarily act in response to, or commit resources to. Efforts to elect a new mayor, for example, that the individual supports but is not actively engaged in, would fall under this category. The 'horizon of influence' is Bossel's broadest horizon. It operates at a large scale and over long time frames. An individual might be aware of events and issues beyond this horizon but it has little effect on their day-to-day thoughts and actions. Climate change, climate change impacts that are yet to manifest, and many forms of environmental degradation often fall beyond the horizon of influence. These horizons depend on circumstances. In resource-poor communities, horizons of responsibility may not extend far beyond the fulfillment of basic needs. Long-term plans are often difficult to pursue.

Bossel's conceptual framework can be applied not only to individuals but also to groups and institutions at larger scales. Institutions may act like individuals and refrain from engagement in issues that are global in scope and/or distant in time, especially if it means making short-term sacrifices. Here again, circumstances and capacity factor in. Developing countries with limited resources may be less inclined to support global initiatives or to undertake long-term programs when they have more immediate concerns to deal with.

One could also expand upon the concept of Bossel's horizons of responsibility, attention, and influence by interpreting it as operating in the opposite direction. Just as institutions may refrain from engagement in issues that are global in scope and/or distant in time, they may also fail to respond to the immediate concerns of a particular community, family, or individual – viewing them as too minor or limited in scope to warrant attention.

Viewed through Bossel's lens, the case studies serve as examples of how co-benefits approaches can bring climate change mitigation and adaptation closer to the horizons of responsibility of individuals, groups, and institutions, and provide incentives for preemptive climate change action. At a local level, the GMRP brings immediacy to the importance of mangrove restoration as a means of preventing coastal flooding by providing communities with opportunities to undertake economically beneficial activities like honey production. The SWITCH project responded to the distant threat of water scarcity by harnessing an alternative water resource to irrigate public green space – an amenity of immediate importance to urban slum communities in Lima. SWMC promoted water conservation by providing alternatives to irrigation-intensive food production at a local scale. In contrast, to date, REDD+ has mainly involved international, national, and provincial partners. It remains to be seen if the program will be successful at downscaling its efforts, acknowledging and responding to the rights of indigenous groups and engaging local communities as partners in sustainable forest management. In all cases, incentives other than the distant promise of reduced emissions and/or lower long-term risk exposure are important factors.

Participatory planning advocates such as Robert Chambers and Somesh Kumar argue that the more local stakeholders participate in and define the purpose, design, and

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implementation of projects, the more likely it becomes that they will take ownership of, contribute to, and profit from their ongoing success (Chambers 2008; Kumar 2002). The GMRP and SWITCH project, leveraged participatory planning and educational initiatives to learn about local priorities, involved communities in the formulation and implementation of projects and informed stakeholders about their human health, environmental, and other effects. SMWC projects involved the direct engagement of local farmers in the Sahel. Together, these cases suggest that the processes of incentives formulation are just as important as the incentives themselves. The design and execution of interventions should take the particular priorities and motivations of local stakeholders into account and inform them about the immediate 'benefits' that co-benefits approaches can provide. Governing bodies and other organizations can embrace local communities in decision-making processes and enlist them as partners, rather than opponents, in the implementation and enforcement of mitigation and adaptation efforts. Participatory planning and capacity building are critical.

At a large scale and over longer time frames, REDD+ Indonesia helps create national economic incentives for climate change mitigation by establishing systems to compete with Indonesia's logging industry through carbon offset markets. The SWITCH project promoted a framework for governing bodies to adopt wastewater recycling as a means of addressing water scarcity and a lack of urban green space at a regional scale. The GMRP provided a means by which agencies in the Guyana government could protect ecosystem services, safeguard the health and prosperity of its constituents, and avoid costly flood-related property damage. Despite the fact that increases in the Sahel's rainfall were due to changes in external factors, SWCM provides evidence that NGO efforts to combat the negative impacts of desertification were effective at a regional scale and encourages the continuation of these efforts. The broader scope of the case studies suggests that local engagement is only a part of the equation; that multi-scalar approaches to climate change mitigation and adaptation are essential. Co-benefits approaches should provide local and regional, immediate and long-term incentives concurrently.

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4.2. Promote long-term integrated impact assessment

Co-benefits approaches and incentivizing climate change mitigation and adaptation will be ineffective if the benefits they promise fail to materialize or have unintended negative impacts. From the perspective of Bossel's horizons, ineffective or counterproductive climate change mitigation and adaptation strategies could dampen an individual's, community's, or institution's resolve to invest in climate change action by leading them to believe that their efforts would be futile.

The quality, depth, availability, and nature of data on the impacts of the case studies vary. All of them involve some form of evaluation. However, methods of evaluation, stakeholders involved, and extent of published documentation differ. For example, REDD+ Indonesia is yet to establish institutions for the quantitative and qualitative monitoring, reporting, and evaluation of program impacts (Santosa, Khatarina, and Suwana 2013). While published data on REDD+ are readily available and relatively thorough at a national and provincial scale, data on local efforts, especially local adaption efforts, are less extensive. Published data on the SWITCH project is also readily available. However, these data focus on the project's immediate outcomes and do not verify the long-term persistence of these outcomes.

Thorough analysis of health-related and ecological factors in tandem was absent in all of the case studies and only the SMCW case study and, to a lesser extent, the GMRP case study include analysis of long-term project evolution. In the GMRP case, evaluation of mangrove seedling loss indicates the probable need for the hybridization of ‘soft’ and ‘hard’ mangrove restoration strategies. In the SMCW case, analysis indicates that, contrary to initial claims, traditional planting practices are unlikely to independently increase local precipitation. Both suggest that the pursuit of co-benefits approaches becomes increasingly valuable when it is possible to verify their impacts and their actual co-benefits and co-harms.

The case studies’ lack of comprehensive, integrated data, although only representative, speaks to the current state of knowledge concerning climate change mitigation and adaptation in general (Hall *et al*. 2012; Nature Climate Change 2013). It suggests the need to further develop methodologies and standards that take long-term outcomes into account and link human health, environmental, and other climate change causes and impacts. Monitoring and evaluation techniques such as Results Based Monitoring, Log Frames, and Outcome Mapping have well-established track records in development practice and are applicable to the assessment of climate change mitigation and adaptation projects. By carefully establishing baselines, indicators, milestones, and targets relevant to climate change-related projects, strengthening attribution of project impacts over extended timeframes, integrating quantitative and qualitative measures of project efficacy, and pursuing interdisciplinary collaboration as a means of bridging divergent perspectives on the appropriate metrics for project success, we stand to strengthen these practices and gain a better understanding of the co-benefits and risks associated with mitigation and adaptation strategies (Lamhauge, Lanzi, and Agrawala 2011; Cheng and Berry 2013; Dinshaw *et al*. 2014; Noble *et al*. 2014; Bours, McGinn, and Pringle 2015; Fisher *et al*. 2015).

It is important to note that the lack of comprehensive, integrated data on co-benefits mitigation and adaptation approaches need not prevent action. Leveraging current scientific knowledge and common sense, and undertaking ‘no regrets’ co-benefits projects now, will provide a head start in safeguarding human and ecological health and, through ongoing assessment, the opportunity to improve upon and refine methods of project implementation (Noble *et al*. 2014; Rizv 2014).

4.3. Foster multidimensional communication networks

Just as incentivizing climate change mitigation and adaptation strategies will be ineffective if the benefits these strategies provide fail to materialize, long-term evaluation of mitigation and adaptation strategies will be ineffective if the lessons such evaluation provides remain cloistered. From the perspective of Bossel’s horizons, climate change is less likely to fall within an individual’s, community’s, or institution’s horizons of responsibility if they are unaware of effective mitigation and adaptation strategies.

A growing body of literature discusses the importance of multi-sectorial, multi-level networks in the implementation of projects and policies and ‘scaling up’ is now recognized as a critical way to address local to global problems (Charbit 2011; Fröhlich and Knieling 2013; Bowen *et al.* 2013). The SWITCH project’s local and national Learning Alliances, the GMRP’s local projects and National Mangrove Coordination Committee, and the integration of national strategy and pilot projects in REDD+ are examples of collaboration and communication which serve to illustrate the importance of multidimensional networks in the implementation of, and dissemination of, co-benefits approaches. Local climate change mitigation and adaptation strategies can inform policy at municipal, regional, or national levels. Inversely, national, regional, or municipal

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policies can provide a legal foundation, direct resources towards, and facilitate the proliferation of bottom-up mitigation and adaptation interventions at a local level. A policy found to be successful in one country might prove successful in another when adapted to local conditions. Municipal regulations might inspire regional or national initiatives on the other side of the globe. The methods and outcomes of a small-scale intervention undertaken in one community can be shared 'horizontally' with another community through peer-to-peer learning. Lessons learned in one discipline have the potential to inform others.

As the SWITCH project's published guidelines suggest, fostering such networks will depend, in part, on the means by which information is shared. This is especially true in resource-poor countries and communities where literacy and access to credible information is limited. Seeking out new ways to make information on climate change mitigation and adaptation strategies more accessible to a lay audience will likely prove critical. Demonstration projects and capacity building programs, the development and the dissemination of easy-to-understand graphic resources, and open source, web-based publication represent a few of the many avenues with potential to democratize information on co-benefits approaches.

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5. Conclusion

Although, in recent years, international negotiations on climate change have shown the potential for progress, their outcomes remain uncertain. Co-benefits approaches represent an opportunity to strengthen climate change mitigation and adaptation efforts, especially in places where populations are expected to be particularly vulnerable to climate change impacts. When considered in combination with Bossel's horizons, the case studies shed light on the ways in which co-benefits approaches can provide incentives to confront climate change impacts and increase awareness of effective mitigation and adaptation strategies where motivation to pursue long-term, broad-based plans, and/or to respond to community priorities, may be constrained. At the scale of the individual and community, co-benefits approaches can bring immediacy to climate change impacts and have the potential to inspire preemptive response at a local level. At a larger scale, co-benefits approaches can motivate governments and other institutions to pursue policies that anticipate climate change impacts and prioritize the participation of individuals and communities in decision-making processes related to climate change mitigation and adaptation. Frameworks for evaluating the synergy between adaptation and mitigation have been proposed that emphasize the intersection of policies and strategies with institutional structure and finances (Duguma *et al*. 2014). However, the complexity of the social processes, often dependent on scale and cultural context of adaptation, can impede or enhance progress (IPCC 2014).

Increased investment in long-term monitoring and evaluation and the development of metrics that bring together health-related, environmental and other indicators, promises to increase the efficacy of co-benefits approaches. Fostering interconnectivity and sharing the lessons such evaluation provides, promises to expand the breadth and depth of their influence. Although a comprehensive understanding of co-benefits approaches and capacity to implement them without fault remains limited, it is important to recognize their potential to stimulate action and generate widespread positive impacts across multiple sectors, scales, and time frames. Pursuing multi-scalar incentives, long-term integrated impact assessment, and multidimensional communication networks in tandem promises to strengthen co-benefits approaches and amplify the effectiveness of climate change mitigation and adaptation.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

The study was funded by the Department of Global Health, the College of the Environment and other participating departments and schools at the University of Washington.

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